PCB RELIABILITY: AUDITING YOUR SUPPLY CHAIN TO INSURE IT

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PCBs are electronic real estate. Establishing the foundation for assembly, there is a direct correlation between the reliability of a final electronic product and the bare printed circuit board. There is much to knowing what it takes as both a buyer and a producer of PPCBs to ensure high-reliability PCB performance.

After selecting the raw materials, backbone fabrication processes (multilayer press, via drilling, copper through hole plating) are the key components of PCB Reliability.

LAMINATES

Qualified through IPC 4101, Laminates meet a particular specification by testing characteristics that include Tg, Td, and CTEs. These characteristics are most often called out in print, which allows the fabricator to choose similarly qualified materials across multiple suppliers.

While North American fabricators tend to limit their amount of Laminate suppliers, Chinese fabricators select from a large class of suppliers ranging from million to billion dollar firms.

Often the smaller, regional suppliers offer cheaper materials; unfortunately, the savings tend to result from low-quality inputs and production short-cuts.

Audit Notes

To ensure the most reliable circuit board, Fabricators should apply the following test: solder float the raw material and calculate the delamination time. Raw materials from globally recognized sources often withstand more than 30 minutes of solder float before exhibiting signs of copper erosion and delamination. In testing alternate material sources, we have found 100% copper erosion and full delamination in as little as five minutes. Unfortunately, all of these materials would be print-compliant as they technically meet the same IPC 4101 standard.

Figure 1: (a) Solder floats of two materials, 260°C for 30 minutes; and (b) 280°C for five minutes.

Figure 1. Solder floats of two materials

MULTILAYER PRESSING

Bonds individual layer cores (C-Stage) together using prepreg (B-Stage)

Critical Parameters vary by material, but typically include the following: rate of rise through critical range, achieving cure temperature, time at cure temperature.

FAILURE MODES

Under-Cure and Over-Cure have succinct impact on both short-term and long-term reliability. Therefore, recipes need to be verified periodically as press components may cause variations over time.

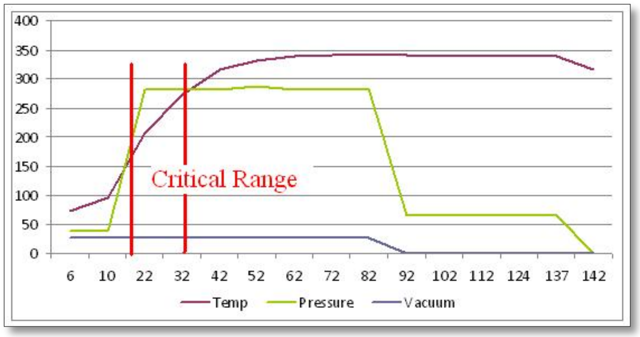

Figure 2. Sample Press Cycle

UNDERCURE OF PREPREG

Table 1. Undercure failure mode for long / short term

Failure Mode	Long / Short Term
Excess Smear / Interconnect Defects	Short & Long Term
Delamination	Short Term
Via Disruption / Excess CTE	Short & Long Term

OVERCURE OF PREPREG

Table 2. Overcure failure mode for long / short term

Failure Mode	Long/Short Term
Rough Hole Wall	Short & Long Term
Surface Embrittlement	Short Term
Via Disruption / Excess CTE	Short & Long Term

Audit Notes

In visiting overseas suppliers, it's common to see a full range of technologies in their capabilities listing. However, more often than not (especially with the small and mid-sized shops), we find that they utilize an outside service called Mass Lamination. In this outsourcing activity, the third party vendor is contracted to print and etch the inner layers, press them together, and then X-ray drill tooling holes that the PCB fabricator uses to align the panels to the drilling machine.

Since most of the overseas fabricators hold advanced quality systems certifications such as IATF16949 (formerly known as TS16949), they are required to certify their vendor base. I've found in all cases when I ask about their controls on the mass lamination vendor, all they are able to provide is that vendor's ISO9000 certification.

Evidence of a well audited / surveyed mass lamination vendor would include full audit notes, copies of thermal profiles, as well as copies of that vendor's own internal auditing frequencies for items such as press planarity, thermal profile, pressure verification, and vacuum checks.

PRESS CONTROL CHECKLIST

The following procedures are recommended to ensure Press Control:

1. Does the press have product thermocouple capability (not just platen thermocouple)?

2. Does it have a vacuum chamber?

3. Does the PLC have capability to store product / build – specific recipes?

4. Does the QC Engineer maintain periodic test results showing that the actual temperatures match desired in both PLC and Product Process Guidelines?

DRILLING

Drill Bit quality is the most important starting point to ensure Drilling quality as it pertains to PCB Reliability. Vital factors for Drill Bit quality include repointing (in-house or out-sourced; automated or manual) and the quality of inspection tools.

Key Factors Fluctuate by Material and Drill Bit

Additionally, key factors vary by material as well as drill bit type. These include feed, speed and retract. Feed is the rate of entry into the material; Speed is the RPM of the drill spindle; and Retract is the rate of exit out the material.

Table 3. Failure Modes of Incorrect Parameters

Failure Mode	Effect
Rough Hole Wall	Rough Plating / Blown Vias

Nail Heading of inner layers	Broken inner layer interconnects after thermal exposure
Impacted Drill Debris	Hole Wall Pull-Away
Excess Smear across interconnects	Long-Term reliability of via connections decreased
Pink-Ring / Delamination	Interconnect separations

Audit Notes – Drill Bits

At all but one supplier I visited in Asia performed the drill bit repoint function in-house. This typically consists of multiple semi-automatic repoint stations and a few drill bit post-sharpening inspection stations.

The repoint stations magnify the drill bit so that the operator can rotate it to align the cutting edge with the sharpening wheel. The machine sharpens the drill point and the operator moves the drill bit to a container.

Once full, the container is passed on to the final inspection station wherein the inspector inspects the drill bit under a stereo zoom microscope.

I asked if I could take a look, after which I made a comment that it looked very good. In fact, it looked so good I said I bet that they don't have many rejections at all, to which they happily agreed. I asked to see the rejection bin and was shown a dusty box with a few drill bits in it. I then asked to see a box of bits that were passed in inspection for repointing. I proceeded to inspect the bits carefully under the scope and stopped at the 3rd bit and asked everyone to take a look. If you looked closely and spent time you could see that half of the cutting edge on the bit was chipped. The problem was that the scope was set up when hole sizes were larger. With via diameters decreasing as the complexity of PCB designs increase, this scope wasn't feasible to use in an inspection function that required a minimum throughput level. The managers were quick to blame the operators but I took the time to explain (through a translator) what the issue was. On my next visit I was glad to be informed that they had been outsourcing drill repoint to a service that utilized AOI inspection as well as fully automated repointing stations, thereby removing the human element from the process.

Audit Notes – Drill Parameters

During a visit to a supplier, I asked many of the below audit questions. I was shown a packet of papers stapled together that had drill feed and speed tables for standard FR4 materials. Basically the operator had to manually enter the parameters into the machine.

One item stuck out to me was that there weren't parameters for high Tg/Td materials that are often used for lead-free capable product. They explained that the operator simply had to reduce the feed rate of the drill bits by 25%. While not technically a violation of industry systems, requiring the operator to perform a calculation is not best practice. What was odd though was that I didn't see a calculator in the entire department and I was pretty sure that this wasn't math you would trust an operator to do in their head.

This lead me to ask them to show me the parameters screen on a machine that happened to be drilling lead-free product. To little surprise, I found that the parameters entered into the drilling machine were straight off of the charts and not adjusted for lead-free product. Drilling with these parameters can lead to rough holes since lead-free capable material is typically more brittle than standard FR4.

AUDITING FOR PROPER DRILLING

It is important to ask the following questions in order to ensure proper drilling:

1. How have feeds and speeds been determined?

2. How many drill bit vendors are used?

3. How many different types of materials are used?

4. How are drilling parameters entered into the machine?

    a. Operators are high risk;
    b. Drill tables are medium risk
    c. Drill management software is low risk.

5. If Repointing is in-house, is it automated or manual?

6. Are repointed bits inspected by an AOI machine or reviewed manually? If manual, inspect the bits yourself and see if the magnification is sufficient to enable quick and accurate inspection of the cutting points.

COPPER PLATING

Primary Desired Outcomes

High tensile strength and elongation properties allow increased expansion and contraction of plating in hole wall under thermal conditioning. Reduced copper plating thickness variation allows thickness readings from samplings to be trusted for entire production lots. Additionally, it also reduces the target set thickness to insure meeting minimum plating requirements.

Tensile Strength and Elongation

Easier-to-use chemistry often results in lower T&E's while chemistry component control is critical to optimizing plating performance. Control requires the following: proper test equipment; frequent testing; control and monitoring of inorganic contaminants (Carbon Treating Schedule).

VARIATION CONTROL

Copper plating systems can be optimized to achieve either higher throughput or higher quality. The key is to balance the two to achieve high reliability at a competitive cost.

PLATING SYSTEM PARAMETERS

In addition to chemistry, plating system set-up contributes greatly to product quality.

1. Plate panels one-high in the plating rack reduce variation via smaller anode area.

2. 24-inch anode-to-anode-distance is optimal distance to ensure production panel area is adequately covered by anode area without being so far as to reduce effectiveness of anodes.

3. Water-submerged cathodes eliminate the possibility of reduced contact due to oxidation of mating metal areas.

4. Chemical submerged anode bars eliminates the possibility of reduced contact due to oxidation of mating metal areas.

5. Mechanical agitation promotes chemistry flow through holes.

6. Vibration helps remove air from microvias and blind microvias.

7. Dual-sided rectification delivers optimal amperage to each side of production panel.

8. Advanced rectification via newer DC and reverse pulse rectifiers have more consistent energy flow.

9. Reducing amps per square foot (11-15 for DC plating) is important as plating at reduced ASF for longer cycle time reduces plating variation and increases throwing power of the chemistry to adequately plate the center of the hole barrels.

AUDITING FOR PLATING

The following checklist ensures a reliable plating process:

1. Contact your supplier's Plating Chemistry supplier and gage their insight.
2. Audit Lab Records to confirm the frequency of testing.
3. Submit Test Vehicles for Reliability Testing (IST, HATS, and Thermal Cycling).
4. Audit Setup against Ideal Setup Checklist.
5. Review Cross Sections and perform Statistical Analysis on Supplier's plating thickness records.
6. Determine if within acceptable Standard Deviation Range

BARE BOARD CLEANING

Ionic Contamination can lead to dendrite growth

Dendritic growth can result in massive shorting across the PCB surface after time in the field. Ionic Contamination is covered under IPC-5704, but it is not often called out in PCB FAB Notes or OEM / CM PCB Specifications.

IONIC CONTAMINATION

Primarily a considerable factor in PCBs with HASL or Pb-Free HASL Final Finish

Fluxes introduce the most contaminants to the PCB surface. However, they are not detectable without Ionograph or Ion Chromatograph testing. Though it will not immediately result in PCB failure, it typically results in field failures in right conditions.

COMBATTING

OEM / Assembly

The easiest method to use is conformal coating. However, if conformal coating is not being used then the best practice is to pre-clean the circuit boards prior to Assembly. This is not typically feasible due to equipment and timing needs and it tends to introduce moisture to the boards. As such, the best method is to rely on the PCB Vendor to control the process prior to bare board shipment.

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CONTROLLING

PCB Fabricators: Clean the Board!

A clean PCB is easier to clean than a dirty one. After soldermask application, UV Bumping closes the pores that can, in turn, entrap the fluxes. Therefore, it is important to follow this process by using a Saponifier or solvent-based mixture during post-HASL PCB cleaning gives the best result to pass IPC cleanliness specifications. Saponifiers are cleaning agents that break-up and disperse flux residue from the PCB surface.

Mechanically Clean the Board

Though not industry standard, PCB fabricators can design or purchase a lateral scrubbing mechanism for use during HASL post-cleaning. Furthermore, it is critical to increase temperatures during scrubbing and rinsing in combination with the aforementioned mechanism. Finally, this process should be monitored by measuring ionic contamination on a frequent basis. This insures mechanisms and chemistries are operating at effective levels.

CONCLUSION

Insuring PCB reliability is not an easy task. But basic knowledge of key contributing processes makes PCB users the most effective auditors. The PCB Suppliers' Key Processes are a valuable and critical tool for managing Supply Chain.